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THE EXHALATION OF OZONE BY ODOROUS PLANTS.

BY DRS. J. M. ANDERS AND G. B. M. MILLER

IN the AMERICAN NATURALIST for April and May of the year 1884, there appeared two articles, by one of us, treating of the "Exhalation of Ozone by Flowering Plants." The reader will there find recorded the results of numerous experiments which were made with the view of ascertaining whether or not plants have the power to generate ozone. The chief conclusions therefrom deduced were as follows: 1. That flowering plants in general are capable of generating ozone, and odoriferous flowers in particular. 2. That foliage plants do not possess this function.

It should be remarked that the present re-investigation of the subject was undertaken with the view either of confirming or disproving the correctness of the above conclusions. Owing to the high importance of the question of the relation of plant growth to the generation of ozone, this course was deemed almost incumbent.

As the more important properties of ozone were discussed in the previous papers, it is not deemed necessary to do so here. The hygienic relations of this substance also received brief attention while its tests received careful consideration; hence to further enlarge upon these phases of our subject, at present writing, would be a work of supererogation. The methods employed in the former experiments were likewise used in the present series. The following apparatus was used: A glass case large enough to contain a dozen or more thrifty growing plants in pots. Its dimensions were, length three and a half feet, width two and a half feet, and height two and a half feet. A portion of the top was left removable, so as to furnish an aperture through which the plants could be placed in the case and again taken out. The tests employed were the Schoenbein paper and paper impregnated with tincture of guaiacum. When exposed to ozone artificially prepared the Schoenbein paper turns quite blue, while the guaiacum paper first turns greenish-blue and finally a bright blue. In the present experiments we also employed the same terminology, viz., "marked," "slight" and "very slight," to denote the degree of blue coloration.

A dozen thrifty plants belonging to the species *Coleus blumei*, not blooming, were first selected and placed within the glass case. The test papers were moistened and suspended on the branches of the plants. After adjusting the removable part of our case, the latter was found to be pretty well filled though not overstocked with plants. For the purpose of detecting any alkaline substance whose presence, it is said, will change the Schoenbein and guaiacum papers in a manner indistinguishable from that produced by ozone, we suspended with the test papers a piece of red litmus, with the results indicated in the following tables. The air on the exterior of the case was simultaneously tested for ozone. In view of the fact that these tests are in an unsatisfactory state, the necessity for taking precautions against interfering conditions must be obvious to the mind of the scientfic reader.

The following table will serve to show the results obtained from the specimens above named for seven consecutive days in the month of June, 1884:

No. experiment.	*Schoenbein.*	*Guaiacum.*	*Schoenbein in open air.*	*Time.*	*State of weather.*	*Litmus (red).*
No. I.........	negative	negative	negative	8 hours	clear	negative
No. II	"	"	———	8 "	"	"
No. III	slight	marked	marked	11 "	"	blue
No. IV........	negative	slight	negative	9 "	"	negative
No. V.........	"	very slight	marked	9 "	"	"
No. VI	"	"	negative	10 "	"	"
No. VII	slight	marked	slight	8 "	"	blue

These results are in exact accord with those previously recorded (supra) by one of us. It should be remarked that whilst two "slight" reactions occurred with the Schoenbein paper, they were probably due to the presence of some alkaline substance, since on the same days the red litmus was changed to a "marked" blue. Thus, after repeated experiments, it would appear certain that it cannot be claimed for non-odorous foliage plants that they are ozone-generating. Though the guaiacum paper gave "slight" reactions in three experiments which yielded no results with the litmus paper, it should be here noted that owing to the fact that this paper (guaiacum) is materially affected by various atmospheric conditions, we did not much rely upon the results obtained from its employ. On the other hand, if proper precautionary measures be taken, the Schoenbein is, doubtless, of all the tests for ozone the most reliable.

We next experimented with odorless flowering plants, selecting ten plants of the species *Fuchsia globosa* and ten periwinkles, species *Vinca rosea*, with the following results:

No. experiment.	*Schoenbein.*	*Guaiacum.*	*Schoenbein in open air.*	*Litmus (red).*	*Time.*	*State of weather.*
No. I	marked	marked	negative	negative	10 hours	clear
No. II	negative	"	marked	"	9 "	"
No. III	"	negative	negative	"	10 "	"
No. IV	very slight	slight	slight	"	13 "	"
No. V	"	negative	"	"	9 "	"
No. VI	"	slight	marked	"	9 "	"
No. VII	negative	"	"	"	10 "	"

During these observations, which were made in the month of July, 1884, the temperature within the case ranged from 80 to 100° Fahr. It will be observed that sufficient ozone was generated in four of the experiments to give one "marked" and three "very slight" reactions; also that the litmus gave no indications of the presence of ammonia. Although they do not rank as active ozone-generators, nevertheless they must, from the facts of the case, be looked upon as sharing this important function in a slight degree. This decision also coincides with what had been previously demonstrated by experiment.

We now made a trial of odorous flowering plants, selecting for this purpose seven roses and seven specimens of *Lilium longiflorum.* After carefully enclosing them within the case, the atmosphere of the latter was tested and simultaneously the air outside, with striking results as shown by the following table:

No. experiment.	*Schoenbein.*	*Guaiacum.*	*Schoenbein in open air.*	*Litmus (red).*	*Time.*	*State of weather.*
No. I	negative	marked	negative	blue	8 hours	clear
No. II	marked	"	"	negative	9 "	"
No. III	negative	negative	"	"	9 "	pa'ly clou'y
No. IV	slight	marked	marked	"	8 "	clear
No. V	marked	"	slight	"	10 "	"
No. VI	"	"	very slight	"	10 "	"
No. VII	"	"	"	"	11 "	"
No. VIII	"	"	negative	"	10½"	"

During these experiments the temperature of the air in the case ranged from 80 to 100° Fahr. The important conclusion arrived at in previous papers,[1] viz., that odorous flowering plants are active and energetic ozone-producers, it will be clear, receives from present researches entire confirmation. Since this function is so actively carried on by odorous flowers, it occurred to us to make a trial of plants whose leaves emit odors but having no flowers. Blooming geraniums having been experimented with while making previous researches into the same subject, and having found them to be capable of generating ozone, it was determined to employ a number of specimens belonging to the genus Pelargonium not in bloom, with a view of ascertaining whether the reactions obtained with flowering geraniums were due to the presence of the flowers, or whether they were due in part to the odorous principles emitted from the leaves of the plants. To our astonishment slight reactions were obtained, as shown by the following record of results:

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[1] Dr. Anders on "Exhalation of Ozone by Flowering Plants," *loc. cit.*, p. 474.

No. experiment.	*Schoenbein.*	*Guaiacum.*	*Schoenbein in open air.*	*Litmus (red).*	*Time.*	*State of weather.*
No. I	very slight	slight	marked	negative	10 hours	clear
No. II.........	negative	negative	"	"	10 "	"
No. III........	"	"	"	"	10 "	"
No. IV	"	"	negative	"	10 "	rainy
No. V.........	very slight	very slight	"	"	10 "	clear
No. VI	negative	slight	"	"	9 "	"
No. VII........	very slight	"	marked	"	9 "	pa'ly clou'y
No. VIII.......	negative	negative	negative	"	10 "	rainy
No. IX	"	marked	marked	"	11 "	clear
No. X.........	marked	slight	slight	"	10 "	"
No. XI	slight	"	negative	"	9 "	cloudy
No. XII........	negative	negative	"	"	10 "	rainy

Although there were but three "very slight" reactions, one "slight" and one "marked" with the Schoenbein obtained in the twelve experiments here recorded; this is not a bad showing when it is recollected that four of the tests giving no indication of ozone were made on rainy days, it having been shown in the former investigations that sunlight or at least good diffused light is an essential condition to the generation of ozone by plants.

Upon this point, however, the evidence afforded by the results of the present set of experiments alone is too slender on which to base positive conclusions, and hence we deemed it desirable to make further observations upon foliage possessed with marked perfume. To aid in clearing up this subject it was next resolved to make tests with pine foliage, possessing the well-known terebinthinate odor, and in the results obtained we were not disappointed.

Seven branches taken from the species *Pinus strobus* were introduced into the case in the upright position, when the same tests were applied as in the experiments on growing plants, with results as follows:

No. experiment.	*Schoenbein.*	*Guaiacum.*	*Schoenbein in open air.*	*Litmus (red).*	*Time.*	*State of weather.*
No. I	marked	slight	very slight	negative	9 hours	clear
No. II.........	"	marked	slight	"	10 "	"
No. III........	"	"	"	"	9 "	"
No. IV	slight	slight	marked	"	10 "	"
No. V.........	negative	negative	"	"	9 "	"

After three days the pine branches turned brown and the leaves rapidly dropped off. These facts doubtless account for negative results after the fourth day. It should be stated that we continued to test them on the sixth and seventh days respectively, and with negative results in both of the latter instances. We were, however, encouraged by the success attending the first three experiments, and resolved to make another trial of pine branches· Accordingly we again selected a half dozen pine branches which moderately filled our little floral chamber, and allowed them to remain only until they began to show a change in color, which change was first observed at the end of the third experiment.

The following results speak for themselves:

No. experiment.	*Schoenbein.*	*Guaiacum.*	*Schoenbein in open air.*	*Litmus (red).*	*Time.*	*State of weather.*
No. I	marked	marked	marked	negative	9 hours	clear
No. II.........	"	slight	negative	"	10 "	clear, partly cloudy
No. III........	"	"	slight	"	10 "	clear

We also made four daily experiments with branches taken from the Norway spruce (*Abies canadensis*) and, as shown by the following record, with happy results:

No. experiment.	*Schoenbein.*	*Guaiacum.*	*Schoenbein in open air.*	*Litmus (red).*	*Time.*	*State of weather.*
No. I	marked	marked	slight	negative	12 hours	clear
No. II.........	"	slight	negative	"	10 "	"
No. III........	slight	marked	"	"	10 "	"
No. IV	marked	slight	marked	"	9 "	"

We, unfortunately, were unable at that time to obtain more foliage of the same character, and thus our investigations were brought to an end. Although a greater number of experiments upon this point could have been desired, when, on the one hand, it is recollected how great and numerous the difficulties connected with the making of such tests, and on the other, the brilliant and very uniform success of the experiments made with pine foliage, it will be readily conceded that these facts furnish abundant evidence of the power the odorous principles evolved from the pine tree have to generate ozone.

From the foregoing, in conjunction with former investigations into the same subject, we are, at present writing, justified in formulating the following conclusions:

First. That flowering plants, including odorous and inodorous, generate ozone, the former, however, much more actively than the latter.

Secondly. That so far as tested scented foliage does possess the power to produce ozone, and in the case of pine or hemlock foliage in a marked degree.

Thirdly. That inasmuch as no reactions occurred on rainy days, it is highly probable that the function demands the influence of the sun's rays or at least good diffused light.

In comparing the present with former conclusions, cited at the commencement of the paper, it will be seen that they differ in so far as relates to foliage plants only, those pertaining to flowering vegetation being perfectly concordant.

As to the mode in which the ozone is developed by plant life, or in other words, as to what is the nature of this ozone-generating function, the following explanation was elsewhere merely suggested (loc cit.): "It is known that the ashes of seeds contains large quantities of the phosphates. It follows that during the formation of the seed there is a rapid metastasis of the phosphorus in the form of phosphoric acid, and the phosphates to that organ of the plant, and it may reasonably be supposed that in the chemico-vital interchanges going on in the ovules, phosphorus is liberated and acted on by the moisture which the leaves are so actively transpiring. * * * The subject, however, merits further investigation." In view of the facts established by present researches the theory of the production of ozone by vegetable growth above cited must be abandoned, and it appears evident, from present premises, that in some way the odoriferous principles emitted, whether from flower or foliage, are chiefly concerned in its formation. It is true we are unable in this manner to account for its production by odorless flowers, unless, as many contend, we grant that all blossoms are either bedecked with or, somewhere in their loose cellular tissue, contain scented nectar which in many so-called inodorous flowers may not be sufficiently pronounced to be perceived by the organ of smell.

It is a well-established fact that wherever fertilization is accomplished by insects, so-called *nectaries* are somewhere found in the flowers. These organs are described by Sachs as follows: "The nectaries are often nothing but glandular portions of tissue on the foliar or axial parts of the flower; very often they project in the form of cushions of more delicate tissue or take the form of stalked or sessile protuberances; or whole foliar structures of the perianth, of the andrœcium or even of the gynœcium, are transformed into peculiar structures for the secretion and accumulation of the nectar."[1]

The proportion of plants where pollination is effected by insects is certainly large, and when we take into account those flowers in which cross-fertilization occasionally results from the aid of insects, this proportion is still very much larger. Whether it can be claimed for all inodorous flowers that they contain a greater or lesser number of nectaries we are not prepared to state, but it is certain that numerous flowers, which are classed as being without fragrance or any other odors, such as the geranium, the passion flower, etc., are visited by insects, and these must therefore contain glandular tissues filled with an alluring secretion. The question also naturally here arises: Are there not flowers that are never visited by insects, which flowers possess these glandular organs?

Our investigations did not include an examination of these organs, but there is evidently an interesting subject here presented for further experimental study.

The theory that the fragrant emanations from flowers, as well as all the various odoriferous substances emitted from plants, stand in close relation to the ozone-producing function in plants likewise receives striking corroboration in the well-known chemical fact that the volatile perfumes and the strongly-scented aromatic substances have the power to convert the oxygen of the atmosphere into ozone.

The application of the results of our experiments to the rather old but highly interesting subject of the cultivation of house plants is of considerable importance. That phase of the question, however, pertaining to flowering plants has been elsewhere treated. It remains to speak of the sanitary relations of the new and additional fact which has been established by the present experiments concerning odorous leaves as ozone-generators. Owing to the fact that few varieties which have markedly odorous leaves are cultivated within doors, their sanitary bearings may be regarded as being slight, the leaves of the geranium and other species usually seen in dwellings being feeble in their ozone-generating properties. Again, it should be remarked that when kept indoors the odors given off both from the flower and foliage are sometimes not only objectionable to the senses, but also may prove detrimental. It is evident that such plants should be discarded.

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[1] Sachs' Text-book of Botany, p. 500.

The case is widely different when we apply the results of our labors to the question of the hygienic value of out-door vegetation, and more particularly of pine groves. Under these circumstances unpleasant odors do not form a positive objection, whilst the species emitting the most pronounced odors are capable of rendering valuable hygienic service by furnishing ozone to the surrounding medium. Since the exhalations from the pine foliage are active agents in generating ozone, it follows that all of the important hygienic advantages of ozone are to be derived, to a marked degree, from the presence of pine woods.[1]

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GLACIAL ORIGIN OF PRESQUE ISLE, LAKE ERIE.

BY T. DWIGHT INGERSOLL.

THE peninsula of Presque isle is an extension of the main land opposite the city of Erie, Pennsylvania, reaching out into Lake Erie in a north-eastern direction. It is crescentic in form, the convex portion facing the lake with the shore line bending toward the mainland, and forming Erie harbor, which is known also as Presque Isle bay. The bay is about four miles in length by about two in breadth, with an entrance on the east. Government operations have made the bay somewhat historical. The vessels of Commodore Perry's fleet were built here in 1813,

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[1] For a fuller discussion of the subject of the sanitary relations of pine forests, see article by J. M. Anders, on "Sanitary Influence of Forest Growth," a paper read before Phila. Go. Med. Society, Oct. 22, 1884.